LECTURE 1
INTRODUCTION

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408450 Computer Networks, Fall 2011/2012
http://www.hlms.hu.edu/

Today's Lecture

- Course outline and goals.
- Tour of Networking

Course Staff

- Instructors
  - Thaier Hayajneh
    - <Dr.Thaier@gmail.com> ,
    - Engineering Hall 3060
- Watch the course web page.
  - Handouts, readings, ..
- Read course boards.
  - "Announce" for official announcements
  - "General" for questions/answers
- Books

Contact information

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Contact Information II

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- Office Hours
  - Is posted at my office
- IM
  - Dr.Thaier at gmail.com
- IM Hours
  - Variable

Note on Textbook

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- *Data Communications and Networking* - Behrouz a. *Forouzan -4th Edition , 2007*.
- We have to derive some material from other sources
  - Rapidly changing field
  - Most books focus on one or two specific topics in great detail
- I may not stick to the flow of the textbook

Course Policies

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- Your work MUST be your own
  - No copying from web or other books without understanding the material
  - Zero tolerance for cheating: You get an F for the course if you cheat in anything however small ⪷ NO DISCUSSION
- Homework is due a week after it is assigned
  - Late assignments will NOT be accepted
- Check the webpage for everything!
  - You are responsible for checking the webpage for updates

Grading

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- 25% for Exam I
- 25% for Exam II
- 50% for Final exam
- 0% for Homeworks & Quizes

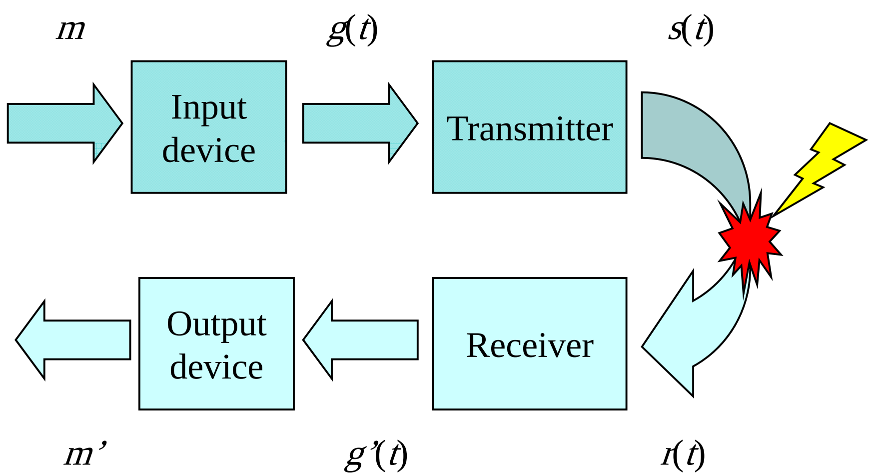
Exam Policies

- Writing must be clear, to the point, legible and unambiguous
- I should be able to understand what you are trying to do/say without verbal explanations later
- No credit for vague answers, unclear steps, magical solutions, etc.

Communication models

- The fundamental purpose of data communication is to exchange information between two entities
  - Information is represented as data and carries meaning currently assigned (depending on a context) to those data
    - Data represents facts, concepts, or instructions in a formalized manner suitable for communication, or processing by human or machines

Simple Communication Model



Simple Communication Model

- *m*: original information message created by sending entity
- *g*(*t*): time varying signal, not suitable for transmission
- *s*(*t*): signal obtained by converting *g*(*t*) into a form that matches the characteristics of the transmission medium
- *r*(*t*): received signal which may be different from *s*(*t*)
- *g'*(*t*): signal obtained by converting *r*(*t*) into a form suitable for output
- *m'*: estimated message produced by destination entity

Simple Communication Model

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- Although simple, the model highlights several communication tasks:
  - Interfacing,
  - Signal generation,
  - Synchronization,
  - Error detection and correction,
  - Flow control,
  - Framing, message formatting

Data Communication Networks

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- Point-to-point communication is the simplest form of data communication
  - Not practical to provide a dedicated wire between each pair of devices
- Communication networks provide efficient means for data communication between multiple devices

How to Draw a Network

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Building block: The Links

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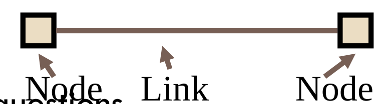

- Electrical questions
  - Voltage, frequency, …
  - Wired or wireless?
- Link-layer issues: How to send data?
  - When to talk – can everyone talk at once?
  - What to say – low-level format?
- Okay… what about more nodes?

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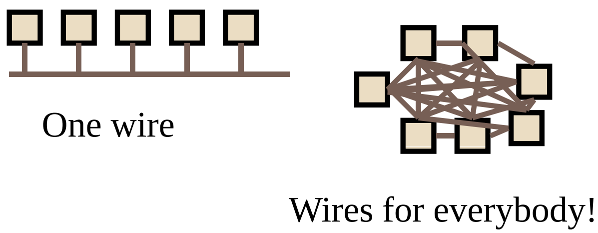
- … But what if we want more hosts?



- Scalability?!

Communication Networks

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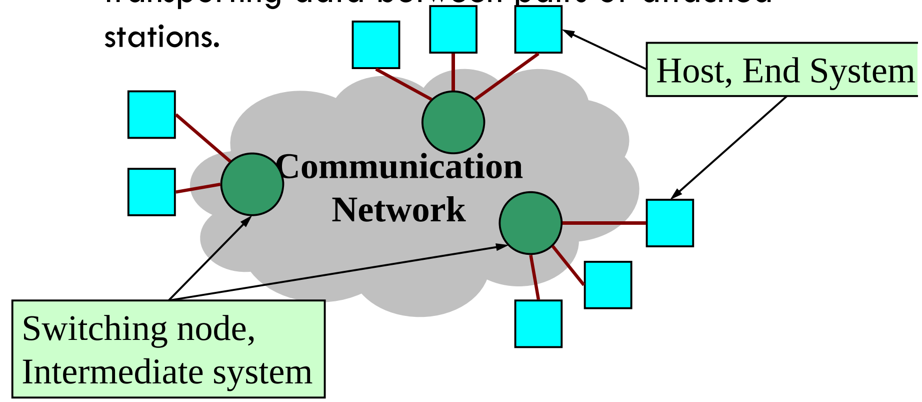
- Network, a collection of nodes capable of transporting data between pairs of attached stations.



What is a Computer Network?

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- Software and hardware infrastructure:
  - It allows access to different types of resources (original purpose)
    - Computing resources, input/output devices, files, databases…
  - It provides a medium through which geographically dispersed users communicated (e.g. e-mail, chatting, teleconferencing)
  - An electronic village
  - An information highway, national information infrastructure
  - Cyberspace – "A consensual [environment] experienced daily by billions of operators, in every nation, …"

Network Communication Tasks

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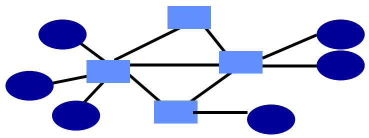
- Several tasks need to be performed to provide computer network functionalities
  - Ensure that transmission facilities exist between end points,
  - Provide physical interfaces to control modems and adapters,
  - Provide access techniques to effectively share resources,
  - Provide addressing, routing, buffering and flow regulation of packets
  - Accomodate peculiarities of users
  - Provide management functions and mechanisms to support distributed applications

Multiplexing!

- Need to share network resources



- How? Switched network
  - Party "A" gets resources sometimes
  - Party "B" gets them sometimes
- Interior nodes act as "Routers" or "Switches"
- What mechanisms can share resources?

Classes of Networks

- Networks are usually defined according to
  - Geographical extent
  - Purpose
  - Implementation

Classes of Networks

- Based on geographical extent, the following classes of networks are identified:
  - Local Area Networks (LANs)
  - Metropolitan Area Networks (MANs)
  - Wide Area Networks (WANs)
  - Radio and Satellite Networks

Local Area Networks (LANs)

- By far, most commonly used class of networks.
  - Maximum distance between nodes is limited to few kilometers.
  - Usually owned by the same organization.
  - Typical data transmission ranges between 10 Mbps (coax cable) to 100 Mbps (fiber optic, category 5 unshielded twisted pair),
  - Several architectures have been standardized (802 LANs):
    - Ethernet (CSMA/CD), Fast Ethernet
    - Token Bus
    - Token Ring
    - FDDI

Metropolitan Area Networks (MANs)

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- A relatively new class of networks, intermediate between LANs and WANs,
- Support moderate (Data, Voice and Video at 1 Mbps) to high data rates,
- MANs are optimized for a larger geographical area than LANs, ranging from several blocks of buildings to entire cities,
- Standards include FDDI, FDDI-II and IEEE 802.6 (DQDB).

Wide Area Networks (WANs)

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- Cover a wide geographical area,
- Communication links are provided by telephone companies, or other common carriers,
- Transmission speeds are usually restricted,
- Transmission quality is inferior to LAN one,
- WAN's architechture is usually more complex than LAN's:
  - Need for efficient routing and congestion control algorithms,
- Many implentations of vendor architectures.

Radio and Satellite Networks

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- Two basic subclasses of wireless networks:
  - Terrestial radio networks,
  - Satellite networks.

Communication Networks

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- Communication networks can be classified as:
  - Broadcast networks, or
  - Switched networks.

Broadcast networks

- In any broadcast network, stations communicate over a shared medium,
- No need for intermediate node,
- Need for medium access control algorithm.
- Three types of broadcast networks:
  - Packet radio networks,
  - Satellite networks, and
  - Local area networks.

Switched networks

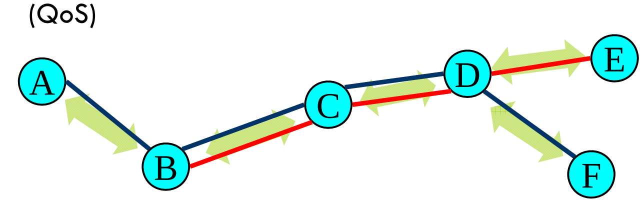
- In switched networks, communication facilities are shared among users.
- Three primary switching techniques:
  - Circuit switching
  - Message switching, and
  - Packet switching.

Switching Techniques: Circuit Switching

- Commonly used in the public telephone system.
- Exclusive dedication of a portion of the available bandwidth to carry traffic between a source and a destination.
- Allocation of the required bandwidth is achieved using:
  - Frequency Division Multiplexing (FDM)
  - Time Division Multiplexing (TDM)

Circuit Switched Networks

- Telephone network typically
  - All resources (e.g. communication links, buffers) needed by a "call" are reserved for its entire duration,
    - Resource reservation (i.e. resources are always available when needed by a call) guarantees „quality of service" (QoS)



Circuit Switching

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- Call requires three phases:
  - Connection phase: a circuit is set up between source and destination,
  - Transmission phase: traffic exchange takes place,
  - Termination phase: the call is disconnected.

Circuit Switching Networks

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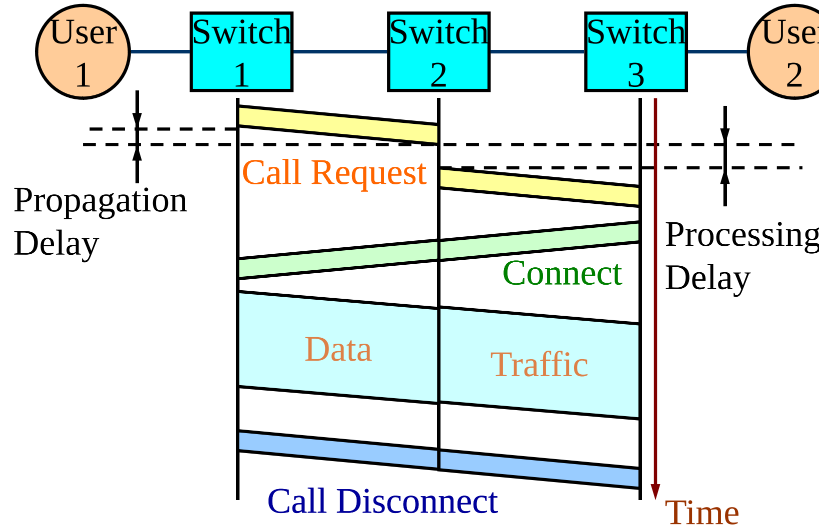

Circuit Switching Networks

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- Delays for setting up connections can be high.
  - Ordinary telephone lines:
    - Call setup is on the order of 5 to 25 seconds after completion of dialing.

Message Switching Networks

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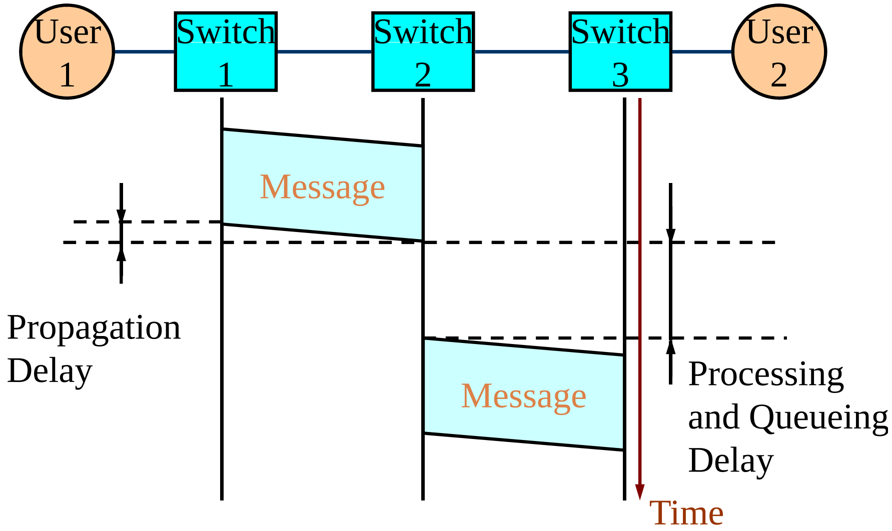
- A physical circuit is shared among multiple users.
  - Leased communication facilities are used.
- Data enters the network in the form of "messages"
  - Messages are stored and subsequently forwarded.
    - No circuit switching delays are involved.
    - Queueing delays occur.
    - Message lengths are slightly longer because of headers.

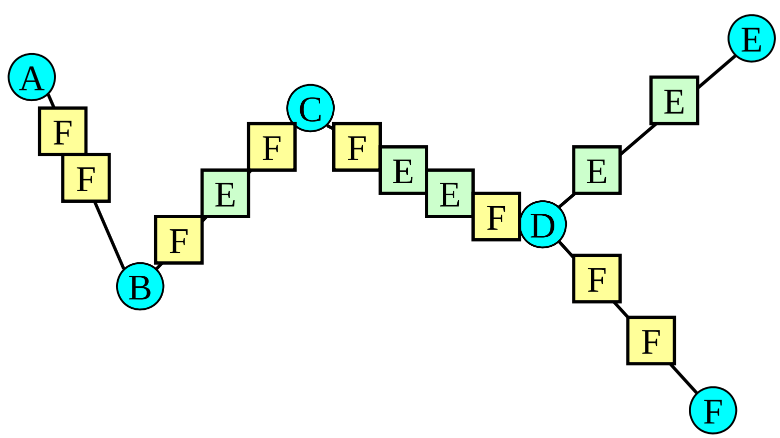
Message Switching Networks



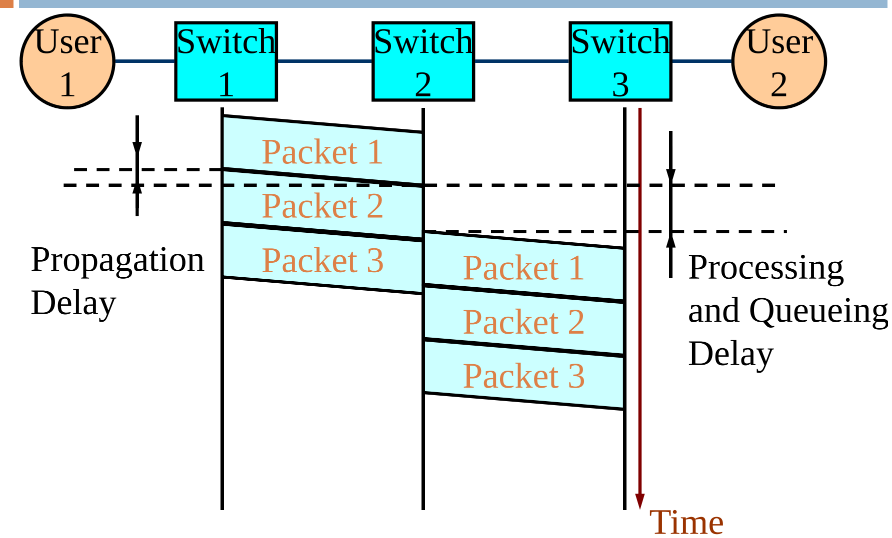
Packet Switching Networks

- Equivalent to message switching for short messages.
  - Maximum message length for transmission is imposed.
  - Any message exceeding the maximum is broken up into shorter units called "packets".
- Packets traversing a network share netwroks resources with other packets – statistical sharing of resources
  - Demand for resources may exceed amount of the resources available: contention

Packet Switching Networks



Packet Switching Networks



Performance Tradeoffs

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- Three types of delay:
  - Propagation delay: time for the signal to propagate from the source to the receiver (depends on the wave propagation speed, in a wire 200 mln m/s = 200 m/μs),
  - Transmission time: time needed to transmit the signal representing a block of data – depends on a link data rate,
  - Processing and queueing delay: time needed to perform tasks necessary to relay a message/packet from one link to another in a given node, as well as time a message/packet has to spend waiting for the access to transmission medium – depends on the processing speed and the network load.

Performance Tradeoffs – Packet Switching

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- A major benefit: the pipelining effect.
- Simultaneous use of communication circuits allows:
  - Considerable gain in efficiency,
    - Shorter delays, despite inclusion of headers for each packet.
  - Lower probability of retransmission,
    - Shorter messages are less likely to have errors than longer ones,
    - Errors do not cause retransmission of entire messages, but only of relatively shorter packets.
  - Packets can be routed independently, possibly minimizing congestion.

Performance Tradeoffs

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- Packet switching provides flexibility in meeting the user needs.
  - Example: the needed rate is 75 kbps while the channel rate is 64 kbps
    - The use of packet switching meets the demands of the user more easily.

Performance Tradeoffs

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- Statistical sharing of resources can be more efficient
  - Consider a 1 Mbps communication link
  - Each user requires 100 kbps when transmitting, but sends 10% of the time,
- Circuit switching:
  - Each caller is allocated 100 kbps capacity,
  - At most 10 callers are supported.
- Packet switching:
  - With 35 ongoing calls, probability that 10 or more callers are simultaneously active is about 0.00174,
  - Can support many more callers, with small probability of contention
- If user traffic is "bursty" (on/off), then packet switching can be more efficient than circuit switching.

Performance Tradeoffs

- The relative performance of circuit switching and packet switching depends on:
  - The quality of service requirements of the application
    - End-to-end delay bounds,
    - Jitter control.
  - The traffic pattern,
    - Burtiness vs constant bit rate,
  - Connection setup overhead.

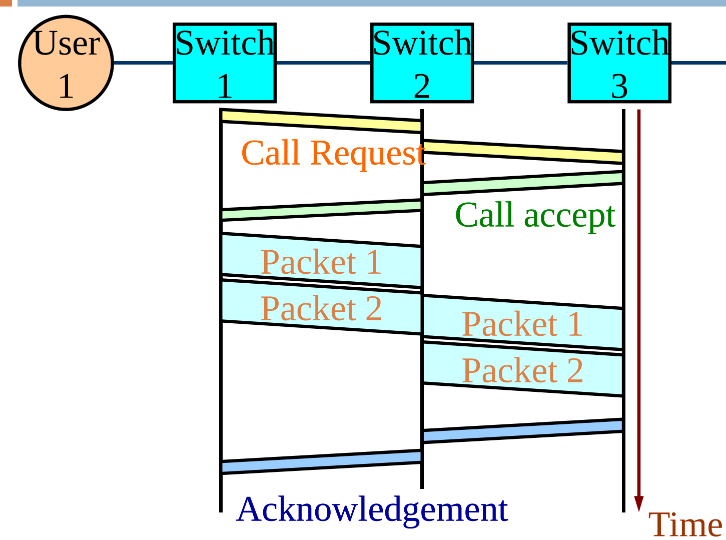
Packet Switching Techiques

- Two basic approaches to packet switching are common:
  - Virtual circuit packet switching
  - Datagram packet switching

Virtual Circuit Packet Switching

- An initial phase is used to setup a fixed route.
  - Similar to circuit switching, except that a delay occurs at each node,
  - Call request and call accept must both wait their turns on transmission.

Virtual Circuit Packet Switching



Virtual Circuit Packet Switching

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- Upon path setup, the virtual circuit appears to the user as a dedicated circuit.
  - In reality, the circuit is shared among multiple users.
- Destination address is no longer required.
  - Only a virtual circuit number is needed to identify the destination.
  - Packets have shorter headers and fixed routing makes fast packet switching possible.

Datagram Packet Switching

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- Datagram Packet Switching does not require a call setup
- For short transactions, it may be faster
- Individual datagrams are routed independently
  - Increases processing overhead at the router
    - Routing table lookups

Virtual Circuit Service Characteristics

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- Guaranteed, reliable delivery
  - Powerful error control
  - Sequencing of packets
  - Detection and suppresion of duplicates
- Congestion control minimizes queueing delays
  - Delays, however, are more variable than they are with dedicated circuits
- Enhanced security

Datagram Service Characteristics

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- The network makes a “best effort” attempt to deliver the packets
  - Each packet is treated as a separate entity with no prior route determination
    - Packets may follow different paths to destination
  - No guarantees for reliable delivery
    - Packets may be lost, duplicated, or may arrive out of order
- The network relies on the user application to enhance the basic datagram service

Analogy

- Telephone service ⇔ virtual circuit
  - User must set up the connection, transmit and finally disconnect.
  - End users have the illusion that they communicate through a dedicated circuit.
  - Data are received in the order they have been transmitted.
- Regular postal service ⇔ datagram
  - Letters are handled independently.
  - No guaranteed delivery. Losses are the user's responsibility.
  - Letters are not necessarily delivered in the order they have been sent.

Analogy

- User perspective:
  - "Unsophisticated" users prefer virtual circuits.
    - The communication subnet handles most of the functions required to provide the requested service.
  - "Sophisticated" users prefer datagram service.
    - Datagram service provides more flexibility to implement particular features.

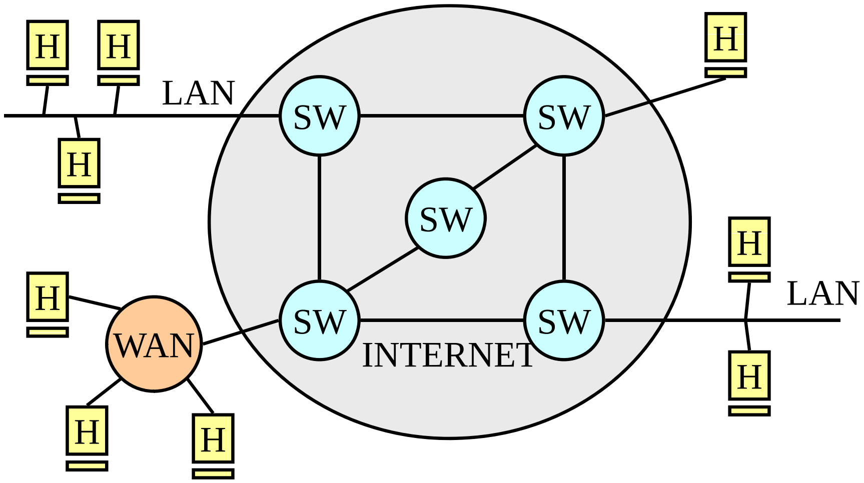
Analogy

- Application perspective:
  - Prior establishment of connection, although desirable, may lead to unacceptable delays for certain types of applications.
    - Request/Reply
  - Features such as error control may be detrimental to time bound applications, such as voice.
    - Few bits in error is far more preferable than lengthly retransmission delays.
    - For voice application a connection set up may be needed but no error control is required.

Connection Semantics

- Literature often uses the term *connection-oriented* and *connectionless* to refer to different network services.
  - Virtual circuit transmission is a special case of connection-oriented transmission
  - Datagram service is a special case of connectionless transmission

Internetworking



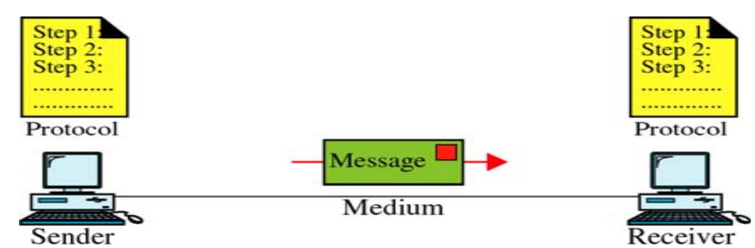
Internetworking

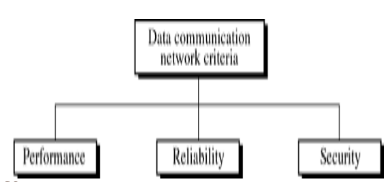
- The main goal is to provide a universal network formed out of physically different networks.
- Internetworking involves complex issues:
  - Different addressing and naming schemes
  - Different routing techniques
  - Different congestion control techniques
  - Different hardware interfaces
  - Connection oriented vs connectionless services
  - Different data unit sizes
  - Different error control techniques

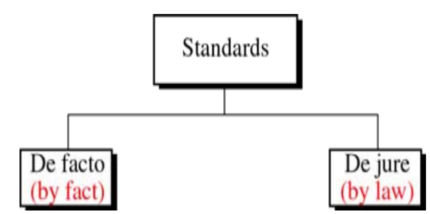
Summary

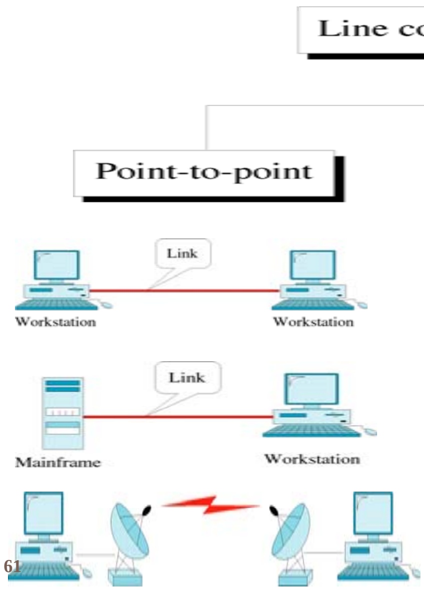
- Introduced the basic concepts of communication networks
- Discussed switching techniques
- Presented different classes of communication networks
- Introduced the concept of Internetworking

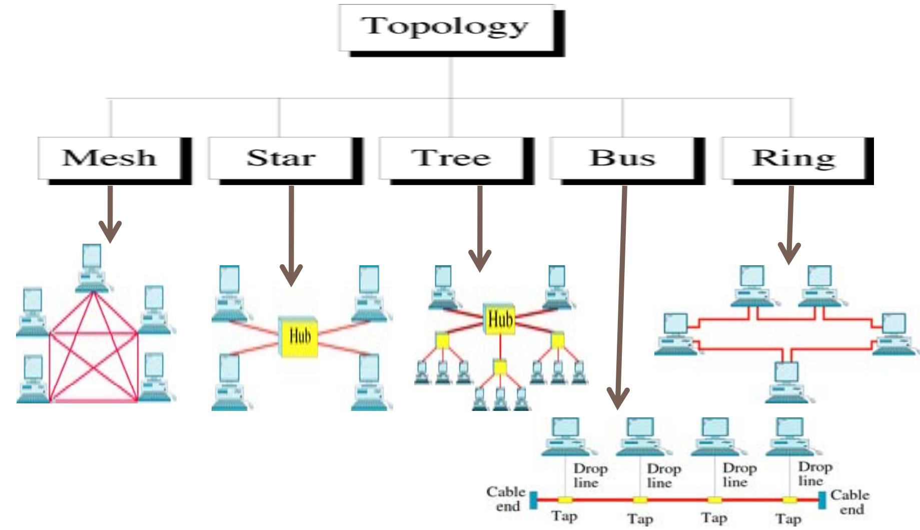
Data Communication System Components



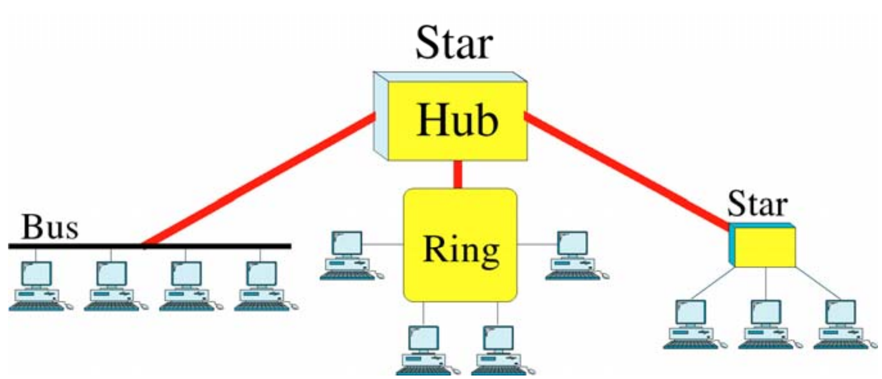


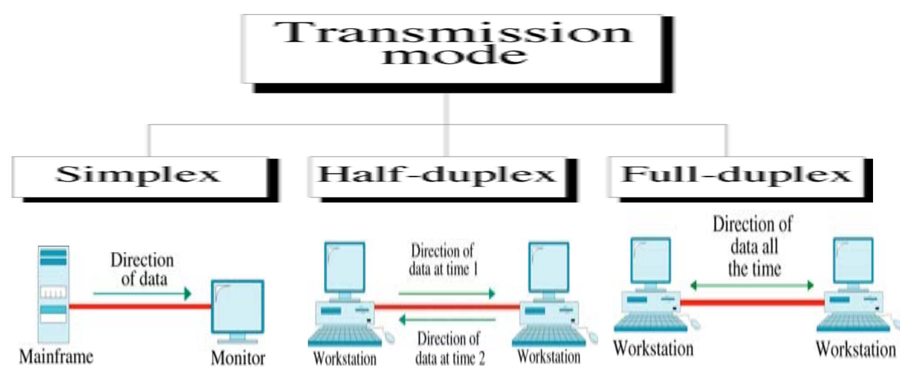


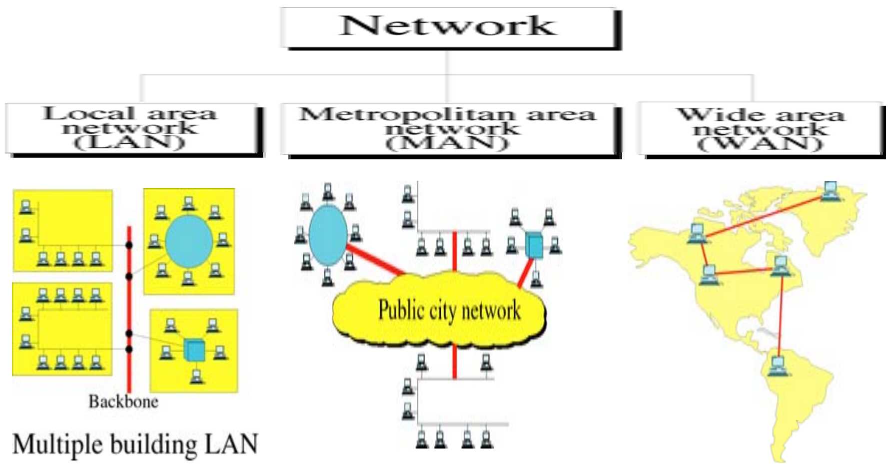




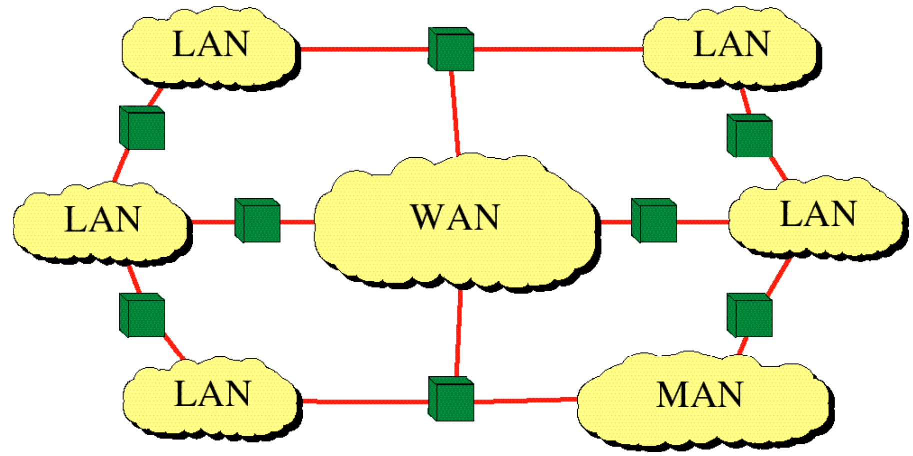
Hybrid Topology







Internetwork (Internet)



“The Internet”

- An inter-net: a network of networks.
  - A set of networks that are connected with each other
  - Networks are connected using routers that support communication in a hierarchical fashion
  - Often need other special devices at the boundaries for security, accounting, ..
- The Internet: the interconnected set of networks of the Internet Service Providers (ISPs) providing data communications services.
  - About 17,000 (much more !!!) different networks make up the Internet
- In order to inter-operate, all participating networks have to follow a common set of rules.

Challenges of the Internet

- Scale: 100,000,000s of hosts
- Heterogeneity:
  - 18,000+ administrative domains
  - Thousands of applications
  - Lots of users
  - Fast links, slow links, satellite links, cellular links, carrier pigeons
- Diversity of network technologies
- Adversarial environment
- Oh, and let’s make it easy to use…

Implementing Packet-Switched Networks

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- Requirements for packets:
  - Header information: Addresses, etc.
  - Data. What is packet size limit?
  - Everybody has to agree on these for interoperability
- How do packets reach destination? Routing
  - Nodes in network forward packets towards destination
  - Routing tells nodes where to send the packets they receive
    - Design questions: What criteria to decide?
      - Destination is a must
      - Source?
      - "Type"?

Routing

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- Who chooses the routes?
  - A human: Static routing
  - Centralized routing (telenet, c.a. 1980s)
  - Distributed routing (Internet, …)
- Distributed routing uses a *Routing Protocol*
  - Many different protocols are in use.
  - Inside an organization: RIP, OSPF, etc
  - Between organizations: BGP

Network Security

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- The field of network security is about:
  - how bad guys can attack computer networks
  - how we can defend networks against attacks
  - how to design architectures that are immune to attacks
- Internet not originally designed with (much) security in mind
  - *original vision:* "a group of mutually trusting users attached to a transparent network" ☺
  - Internet protocol designers playing "catch-up"
  - Security considerations in all layers!

Bad guys can put malware into hosts via Internet

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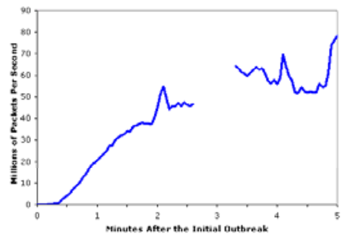
- Malware can get in host from a virus, worm, or trojan horse.
- Spyware malware can record keystrokes, web sites visited, upload info to collection site.
- Infected host can be enrolled in a botnet, used for spam and DDoS attacks.
- Malware is often self-replicating: from an infected host, seeks entry into other hosts

Bad guys can put malware into hosts via Internet

- Trojan horse
  - Hidden part of some otherwise useful software
  - Today often on a Web page (Active-X, plugin)
- Virus
  - infection by receiving object (e.g., e-mail attachment), actively executing
  - self-replicating: propagate itself to other hosts, users
- Worm:
  - infection by passively receiving object that gets itself executed
  - self- replicating: propagates to other hosts, users

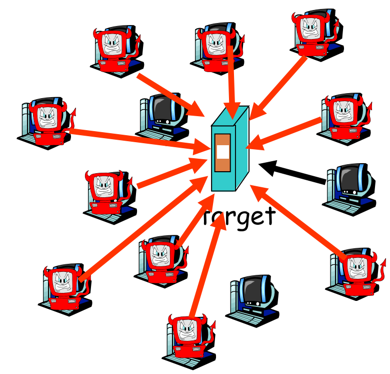
Sapphire Worm: aggregate scans/sec
in first 5 minutes of outbreak (CAIDA, UWisc data)



Bad guys can attack servers and network infrastructure

- Denial of service (DoS): attackers make resources (server, bandwidth) unavailable to legitimate traffic by overwhelming resource with bogus traffic

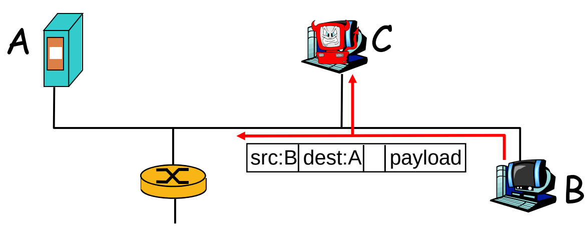
1. select target
2. break into hosts around the network (see botnet)
3. send packets toward target from compromised hosts



The bad guys can sniff packets

Packet sniffing:

- broadcast media (shared Ethernet, wireless)
- promiscuous network interface reads/records all packets (e.g., including passwords!) passing by



- Wireshark software used for end-of-chapter labs is a (free) packet-sniffer

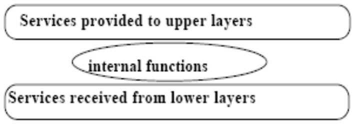
Layering Concept

- The complete communication system is broken down to a set of layers. Each layer will serve the one above it, and uses the services provided by the layer below it.
- The layering strategy is adopted in almost all organizations in order to simplify, and streamline the operation.

Definitions:

- *Protocol*: a certain set of rules that must be followed by all the systems that wish to communicate
- *Peer processes*: similar processes on different machines/systems/networks doing the same job & communicate according to a certain protocol
- *Network architecture*: is the set of network layers

Layer Interaction



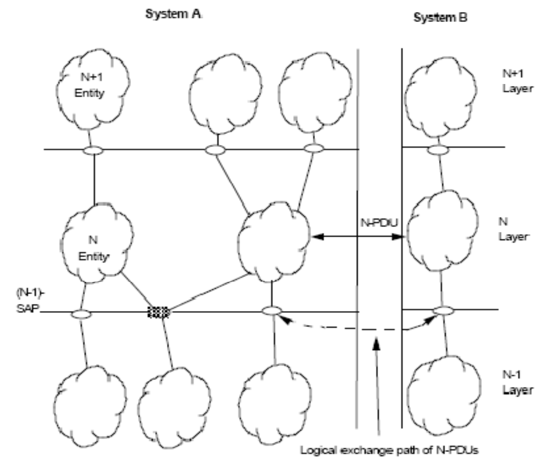
- Each layer (N) consists of one, or more, N-entities (may be different).
- N-entities in one system communicate with N-entities in another system.
- Entities are active processes that implement the layer's functions.
- N-Entities in different systems exchange N-layer protocol data units (N-PDU) (*virtually*)
- *N-entities* provide services to (N+1)-entities, and receive service from (N-1) -entities:
  - N-Protocol Data Unit (N-PDU) is passed with Interface Control Information (ICI) to N-1 layer: *Interface Data Unit (IDU)*
  - (N-1)-Service Data Unit (N-SDU) is received and processed by layer N-1

Layer Interaction

Service primitives specify the type of service

· ***Service parameters*** are passed to service primitives (N-entities contain several service primitives)

· Interface to N-entities is through ***service access points*** (SAP).



Layer Design Issues

- Connection mode
  - Connection-oriented
  - Connectionless
- Data Unit Size: Maximum and minimum data unit sizes
  - *maximum* data unit size is required for error detection, and to prevent hogging of the channel
  - *minimum* data unit size is required for efficient utilization of the bandwidth, and for the correct operation of some protocols
- If a data unit is *too large:*
  - use *segmentation* at the source: *break the data unit into shorter segments*
  - use *reassembly* at the destination: *combine the shorter segments into the original data unit*
- If a data unit is *too small:*
  - use *blocking* at the source: *combine several data units into one*
  - use *unblocking* at the destination: *retrieve the original PDUs*

- *Data transfer mode (types of channels)*
  - *Simplex, Half Duplex, Full Duplex*
- *Addressing:* source and destination addresses
- *Logical channel creation and identification*

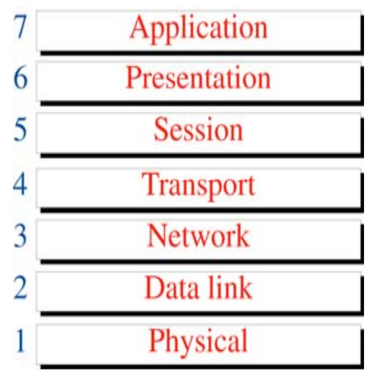
The OSI Reference Model

The Seven Layer Model:

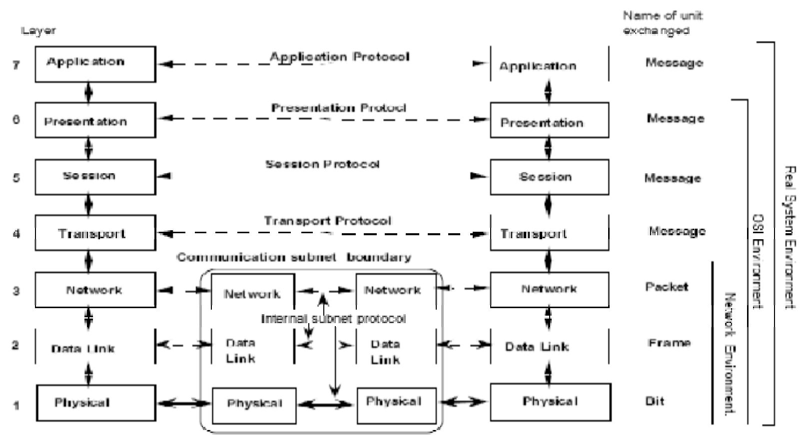
· The OSI reference model consists of 7 layers

· The layers are divided into 3 enclosed sets (environments):

1. **Network Environment:** Concerned with communication over the network.
2. **OSI Environment :** Network environment layers + layers that serve the application.
3. **Real System Environment:** OSI Environment + application itself.



OSI Model



Network Environment

1. The Physical Layer: Physical & electrical interface to the communication channel.
Physical : Medium of transmission (wires)
Electrical: Current, voltage or optical sources, Modulation technique, Establishment & termination of connections

2. The Data Link Layer: Provides error-free data transmission between individual machines on the same network: Error checking; Request for retransmission; Acknowledgments; Detection of duplicates; Flow (congestion) control.

3. The Network Layer: Responsible for packet delivery network-wide: Routing across the network, Addressing, Reliable network-wide data delivery, Flow control (Across network)

The above 3 layers serve *network-related* functions: Deliver data safely, and in order between any 2 machines

OSI Environment

4. The Transport Layer: Provides reliable transfer of data independent of the type and number of networks involved:

- Breaks long messages into packets @ transmitter
- Creates messages from packets @ receiver
- Implement broadcast and multicast services
- Multiplex several transport connections on one network connection
- May create several network connections in order to serve one transport connection
- Provides several (5) classes of service, depending on network characteristics.

5. The Session Layer: It manages sessions by providing primitives that handle
the station dialogs. It can be absent, or merged with the transport layer.

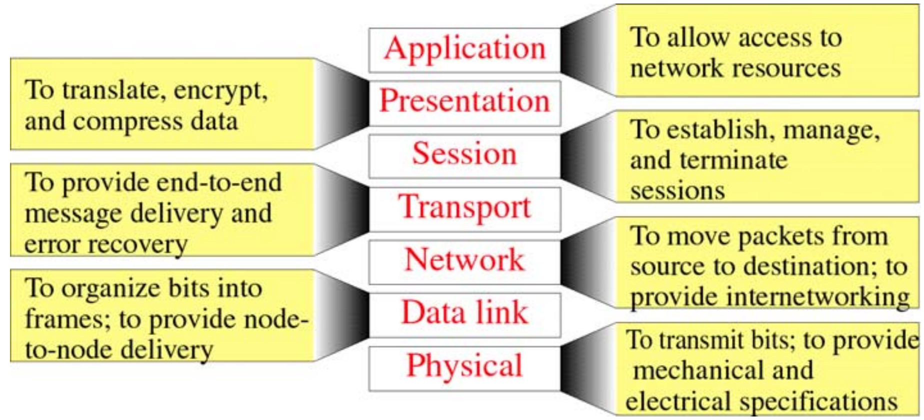
6. The Presentation Layer: Provide machine-independent data representation:
Performs data conversion to and from an abstract form, in order to overcome code incompatibilities

Real System Layers

- 7. The Application Layer: User Applications, e.g., electronic mail & file transfer, Factory-floor communication, Distributed data-base systems, Network file servers, Network virtual terminal
- *Example:*

Layer	Function
Application	File Transfer
Presentation	Convert to the abstract notation
Session	Set up & terminate connection
Transport	Break file into packets in sequence
Network	Route packets to destination
Data Link	Transmit packets error-free between adjacent nodes; flow control
Physical	Transmit raw data on cable

Layer Functions



The TCP/IP Reference Model

- The TCP/IP suite of protocols was developed during the ARPANET project.

1. The physical layer:
defines the interface between the physical medium and the communicating device, e.g., twisted pairs, fibers, etc.

2. The network access layer:
defines procedures for data exchange between the communicating system and the network, e.g., Ethernet, token ring, etc

3. The internet layer: defines procedures for routing and addressing of data Units, e.g., The Internet Protocol (IP) is used for addressing, and routing, and is a connectionless protocol